

Claims

What is claimed is:

1. A device, comprising:

a linear optical cavity having first and second optical reflectors to reflect light at a laser wavelength and to transmit light at a pump wavelength different from the laser wavelength, wherein said first reflector selectively reflects only light linearly polarized in a first direction and said second reflector selectively reflects light linearly polarized in a second direction;

a laser gain section in said linear optical cavity to produce optical gain at the laser wavelength by absorbing the pump light;

first and second optical polarization elements in said linear optical cavity and respectively located on two opposite sides of said laser gain section to make counter-propagating light beams at the laser wavelength reflected from said first and second optical reflectors to have orthogonal polarizations between said first and second optical polarization elements; and

an optical filter located in said linear optical cavity between said first and second optical polarization elements to selectively transmit a single mode at the laser wavelength supported by said linear optical cavity.

2. The device as in claim 1, wherein said linear optical cavity is a linear fiber cavity, and wherein said laser gain section is a doped fiber segment, and wherein said first and said second reflectors are fiber Bragg gratings.

3. The device as in claim 2, wherein said fiber Bragg gratings are reflective to light at the laser wavelength and are transmissive to light at the pump wavelength.

4. The device as in claim 4, further comprising a pump reflecting fiber Bragg grating positioned to reflect light at the pump wavelength transmitting through said laser gain section back to said laser gain section.

5. The device as in claim 1, wherein said first polarization element is a quarter-wave plate and said second polarization element is a three-quarter-wave plate.

6. The device as in claim 5, wherein said quarter-wave plate is oriented to have a principal axis at a 45 degree with respect to said first direction, and wherein said three quarter wave plate is oriented to have a corresponding principal axis at 45 degrees with respect to said second direction.

7. The device as in claim 1, wherein each of said first and said second polarization elements is a quarter-wave plate.

8. The device as in claim 7, wherein said first polarization element is oriented to have a principal axis at a 45 degree with respect to one said first direction, and wherein a corresponding principal axis of said second polarization element is at -45 degrees with respect said second direction.

9. The device as in claim 1, wherein said optical filter is a Fabry-Perot filter.

10. The device as in claim 1, wherein said optical filter includes two fiber Bragg gratings in a fiber.

11. The device as in claim 1, wherein said optical filter is optical bandpass filter with a flat spectral top transmission response.

12. The device as in claim 11, wherein said optical filter includes more than two Bragg gratings in a fiber.

13. The device as in claim 1, further comprising a laser control mechanism engaged to said linear optical cavity to adjust an optical path length of said linear optical cavity in response to a control signal and to tune a wavelength of laser output from said linear optical cavity.

14. The device as in claim 1, wherein the first direction of said first optical reflector is orthogonal to the second direction of said second optical reflector.

15. The device as in claim 1, wherein the first direction of said first optical reflector is parallel to the second direction of said second optical reflector.

16. A device, comprising:

a first polarization-maintaining (PM) fiber section having a first fiber grating to reflect light at a laser wavelength and to transmit light at a pump wavelength different from the laser wavelength;

a doped fiber gain section to produce optical gain at the laser wavelength by absorbing light at the pump wavelength from said first PM fiber section;

a quarter-wave plate optically coupled between said first PM fiber section and a first side of said doped fiber gain

section and oriented to covert light from said first fiber grating into a first circularly polarized light;

a second PM fiber section having a second fiber grating to reflect light at the laser wavelength and to transmit light at the pump wavelength;

a three-quarter-wave plate optically coupled between said second PM fiber section and a second side of said doped fiber gain section, and oriented to convert light from said second fiber grating into a second circularly polarized light orthogonal to said first circularly polarized light; and

an optical filter optically coupled between said first and said second fiber gratings to produce a peak transmission for light at the laser wavelength and being transparent to light at the pump wavelength.

17. The device as in claim 16, wherein said first PM fiber section is polarized along a first polarization direction and said second PM fiber section is polarized along a second polarization direction orthogonal to said first polarization direction.

18. The device as in claim 16, wherein said first PM fiber section is polarized along a first polarization direction and said second PM fiber section is polarized along a second

polarization direction parallel to said first polarization direction.

19. The device as in claim 16, wherein said first fiber grating is a sampled fiber grating to produce a plurality of reflection bands.

20. The device as in claim 19, wherein said optical filter is a comb filter having a plurality of transmission peaks to select one of the reflection bands to transmit.

21. The device as in claim 20, wherein said comb filter includes two fiber gratings in a fiber that are spatially shifted from one another.

22. The device as in claim 21, wherein said two fiber gratings are chirped gratings.

23. The device as in claim 16, wherein each of said quarter-wave and said three-quarter-wave plates comprises a PM fiber.

24. The device as in claim 16, wherein said first fiber grating is a tunable fiber grating.

25. The device as in claim 16, further comprising a temperature compensating mount to hold at least two different locations of said fiber sections to passively compensate for a change in said fiber sections due to a variation in temperature.

26. The device as in claim 25, wherein said temperature compensating mount has a negative thermal expansion coefficient.

27. The device as in claim 16, wherein said doped fiber gain section comprises a doped silica fiber.

28. The device as in claim 16, wherein said doped fiber gain section comprises a doped phosphate fiber.

29. The device as in claim 16, wherein said doped fiber gain section comprises a doped fluoride fiber.

30. The device as in claim 16, wherein said doped fiber gain section comprises a doped bismuth fiber.

31. The device as in claim 16, wherein said doped fiber gain section comprises a semiconductor optical amplifier.

32. A device, comprising a fiber line having an input end which receives a pump beam at a pump wavelength and an output end which exports a residual of the pump beam and a laser beam at a laser wavelength shorter than the pump wavelength, said fiber line comprising a first fiber laser which comprises:

first and second fiber gratings spaced away from each other to form a linear fiber optical cavity and each configured to reflect light at the laser wavelength along a linear polarization direction and to transmit light at the pump wavelength;

a doped fiber gain section between said first and said second fiber gratings to absorb the pump beam and to produce and amplify the laser beam;

a first fiber polarization element coupled between said first fiber grating and said doped fiber gain section and configured to convert light reflected from said first fiber grating at the laser wavelength into a first circularly polarized light;

a second fiber polarization element coupled between said second fiber grating and said doped fiber gain section and to convert light at the laser wavelength reflected from said second fiber grating into a second circularly polarized light orthogonal to polarization of said first circularly polarized light; and

an optical fiber bandpass filter optically coupled between said first and said second fiber gratings, said optical fiber bandpass filter configured to be transparent to the pump beam and to select a laser mode at the laser wavelength to transmit while rejecting other laser modes at the laser wavelength.

33. The device as in claim 32, wherein said fiber line further comprises a second fiber laser to receive output pump light at the pump wavelength from said first fiber laser and to convert part of received pump light into a second laser beam at a second laser wavelength different from the laser wavelength, wherein said second fiber laser transmits the laser beam from said first fiber laser and the fiber line outputs laser beams at both the laser wavelength and the second laser wavelength.

34. The device as in claim 33, wherein said second fiber laser comprises:

first and second fiber gratings spaced away from each other to form a linear fiber optical cavity and each configured to reflect light at the second laser wavelength and to transmit light at the pump wavelength and the laser wavelength;

a doped fiber gain section between said first and said second fiber gratings to absorb the pump beam and to produce and amplify the second laser beam at the second laser wavelength;

a first fiber polarization element coupled between said first fiber grating and said doped fiber gain section;

a second fiber polarization element coupled between said second fiber grating and said doped fiber gain section, wherein said first and said fiber polarization elements make counter-propagating beams at the second laser wavelength to have mutually orthogonal polarizations; and

an optical fiber bandpass filter optically coupled between said first and said second fiber gratings, said optical fiber bandpass filter configured to be transparent to the pump beam and light at the laser wavelength and to select a laser mode at the second laser wavelength to transmit while rejecting other laser modes at the second laser wavelength.

35. The device as in claim 32, wherein each of said first fiber polarization and said second fiber polarization element is a quarter wave plate.

36. The device as in claim 32, wherein said first fiber polarization element is a quarter wave plate and said second fiber polarization element is a three quarter wave plate.

37. The device as in claim 32, further comprising a pump reflecting fiber grating in said fiber line to reflect light at

the pump wavelength that transmits through said doped fiber gain section back to said fiber gain section.

38. The device as in claim 32, further comprising a doped fiber amplifier in said fiber line to receive output pump light at the pump wavelength and the laser beam from said first fiber laser to amplify the laser beam.

39. A method, comprising:

forming a linear optical cavity in a fiber strand with first and second fiber Bragg reflectors respectively formed in first and second polarization-maintaining fibers spaced from each other and a fiber gain section between the fiber Bragg reflectors, wherein each fiber Bragg reflector reflects light at a laser wavelength and to transmit light at a pump wavelength different from the laser wavelength, and wherein the fiber gain section absorbs light at the pump wavelength to produce an optical gain at the laser wavelength;

providing an intra-cavity filter in the linear optical cavity to select a single cavity mode to lase; and

controlling light polarization in the linear optical cavity to make counter-propagating light beams at the laser wavelength to have orthogonal polarizations in at least the fiber gain section and to make said intra-cavity filter to transmit light

reflected from said first and said second fiber Bragg reflectors.

40. The method as in claim 39, wherein the control of the light polarization is achieved by using a quarter-wave plate between the first fiber Bragg reflector and the fiber gain section and a three-quarter-wave plate between the fiber gain section and the second fiber Bragg reflector.

41. The method as in claim 39, wherein the control of the light polarization is achieved by using a first quarter-wave plate between the first fiber Bragg reflector and the fiber gain section and a second quarter-wave plate between the fiber gain section and the second fiber Bragg reflector.

42. The method as in claim 39, further comprising:
forming a second linear optical cavity in the fiber strand to receive optical output from the linear optical cavity, wherein the second linear optical cavity is formed of third and fourth fiber Bragg reflectors spaced from each other and a second fiber gain section between the fiber Bragg reflectors, wherein each fiber Bragg reflector reflects light at a second laser wavelength and to transmit light at the pump wavelength and the laser wavelength, and wherein the second fiber gain

section absorbs light at the pump wavelength to produce an optical gain at the second laser wavelength; and

coupling a single pump beam at the pump wavelength into the first linear optical cavity to produce the laser beam at the laser wavelength while using a residual of the single pump beam to produce the laser beam at the second laser wavelength in the second linear optical cavity.

43. The method as in claim 39, further comprising forming an additional fiber gain section to receive laser light at the wavelength and residual pump light at the pump wavelength from the linear optical cavity to amplify the received laser light.